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ABSTRACT

Meta-analysis techniques were used to summarize the results concerning gender differences reported in doctoral dissertations on visual spatial skills. Dissertations were chosen because they are not subject to the selection process of journals, which may bias results toward large effects. An analysis of 150 independent data points in 43 dissertations indicated an overall effect size of 0.205. A majority of these dissertations used college freshmen and sophomores as subjects. When the scores were partitioned into the categories of spatial perception, mental rotation, and spatial visualization, the effect sizes were 0.034, 0.433, and 0.171, respectively. These effect sizes are smaller than those reported in a recent meta-analysis of journal articles using the same ability categorization. When test results were recategorized using a task complexity scale, gender differences increased with the complexity of the task. When scores were partitioned by task complexity (recognition, manipulation, and multiple tasks), effect sizes were 0.131, 0.280, and 0.243, respectively. Within the spatial manipulation category, effect sizes became larger as the age of the subject increased. Four tables present the data. One appendix lists bibliographic information about the 43 dissertations, and two appendices classify the tests and list them by dissertation. (Author/SLD)

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GENDER DIFFERENCES IN VISUAL SPATIAL SKILLS

A META-ANALYSIS OF DOCTORAL THESES

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Abstract

Meta-analysis techniques were used to summarize the results reported in doctoral dissertations on visual spatial skills. Dissertations were chosen because they are not subject to the selection process of journals which may bias results toward large effects. An analysis of 150 independent data points reported in 43 dissertations indicated an overall effect size of .205. When the different scores were partitioned into the categories of spatial perception, mental rotation, and spatial visualization, the effect sizes were .034, .433, and .171 respectively. These effect sizes are smaller than those reported in a recent meta-analysis of journal articles using the same ability categorization. When the test results were recategorized using a task complexity scale, gender differences increased with the complexity of the task. When the scores were partitioned by task complexity (recognition, manipulation, and multiple tasks), the effect sizes were .131, .280, and .243 respectively. Within the spatial manipulation category, effect sizes become larger as the age of the subject increased.

Introduction

Gender differences in mathematical abilities have become of wide interest to researchers in the recent past. Possibly related to differences in mathematical abilities is gender differences in spatial skills. The research described below will describe the gender differences as reported in doctoral dissertations conducted from 1972 to the present. Dissertations were chosen because they are not subject to the selection process of journals which may bias the results toward large effects.

The meta-analysis reported here is essentially a replication of the Linn and Petersen data collection method focusing instead on dissertations. This is an attempt to overcome the "file drawer" effect (Rosenthal, 1979) which asserts that non-significant differences might not have been published as readily in the journals reviewed in the Linn and Petersen analysis.

Related Research

Numerous analyses have been performed to discern the differences in visual-spatial skills between the two sexes (Maccoby & Jacklin, 1974; McGee,1979; Linn & Petersen, 1985). Based upon the studies reviewed by Maccoby and Jacklin, a meta-analysis was performed by Hyde (1981). This data was then reanalyzed through a meta-analysis performed by Rosenthal and Rubin (1982). McGee (1979) conducted a literature review of techniques and approaches to the study of spatial abilities. Linn and Petersen then performed a meta-analysis on studies reported in specific journal articles, subsequent to Maccoby and Jacklin's review in 1972, up to 1982.

Four different research perspectives to this research question have been taken: differential, psychometric, cognitive, and strategic. In the differential perspective, four sources of differences in visual spatial skills have been investigated. The first of these is an environmental source examining evidence that improvement in perceptual judgements occur as a function of controlled practice and training. A genetic source suggests that spatial abilities may be enhanced by an X-linked, recessive gene. A hormonal source suggests that high body androgenization is associated with low spatial scores among males and with high spatial scores among females. This would seem to indicate that at least a minimum androgen level is required for normal spatial ability. The suggestion made is that there exists a sex-linked influence on within-sex variation in somatic androgenicity. The neurological source suggests that the right cerebral hemisphere is specialized for spatial processing and that males have greater hemisphere specialization than females.

Beyond the differential perspective, the other three perspectives that have been taken in studying gender differences in visual-spatial skills are a psychometric approach used to define various spatial factors, a cognitive approach used to identify the various cognitive processes used in performing spatial tasks, and finally the strategic perspective used to identify the qualitatively different strategies used to solve a task.

Through these four different perspectives, three different categories of spatial ability were defined by Linn and Petersen (1985). These categories are spatial perception, mental rotation, and spatial visualization. Spatial perception tasks require the subject to determine the spatial relationships with respect to the orientation of their own bodies, in spite of distracting information. Examples include the Rod and Frame Test and Piaget's Water Level Task. Mental rotation tasks require the ability to rotate a two- or three-dimensional figure rapidly and accurately. Examples include Shepard and Metzler figures, Flags and Cards,

and Primary Mental Abilities Test - Space. Spatial visualization tasks are associated with those spatial ability tasks that involve complicated, multistep manipulations of partially presented information. These tasks are distinguished from others by the possibility of applying multiple solution strategies. These tasks involve analytic strategies. Examples include the Embedded Figures Test, the Hidden Figures Task, and Paper Folding.

The meta-analysis of visual-spatial research performed by Linn and Petersen (1985) drew the following conclusions:

1. The speculative link of sex differences in spatial ability to the biological changes in adolescence may have been based more on the limited number of convincing studies with preadolescent subjects than on a lack of differences between boys and girls on spatial ability tasks prior to adolescence. Sex differences on spatial perception exist by age 8 and persist across the life span. Reasoners who depend more or primarily on gravitational/kinesthetic cues may outperform those who use an analytic procedure and rely on visual features.
2. Sex differences are detected as soon as mental rotation can be measured. Females have longer response times than do males. Slower performance may reflect greater caution on the part of females. Sex differences may result from a differential rate of rotation, differential efficiency in strategy application, differential use of analytic processes, or differential caution.
3. Spatial visualization is equally difficult for both sexes. This ability is difficult to differentiate from general ability.

Based upon an analysis performed on test norm data, by Cleary and Hengkietisak (1989), the size of gender differences varies with the complexity of the task. Males seem to perform better at more complex tasks. With this possibility in mind, the tests were recategorized using a categorization scheme developed by John Eliot and Ian Macfarlane Smith (1982). They have collected a series of 386 spatial tests and classified them into ten categories, with each category of the first ten being of a higher level of task demands. The remaining three categories contain tests which require more than one problem solution per item or which presented many different types of items in a single page. Due to small sample sizes, these categories were further collapsed into a recognition division, a manipulation division, and a multiple task division. The recognition division includes those tasks involving "the perception and retention of visual forms" (Eliot & Smith, 1983). The manipulation division contains tests which appeared to require "the mental manipulation of visual shapes" across a two-dimensional plane. The three multiple-task categories contain tests with items of no particular complexity level. A sample of tasks included within each category are displayed in Table 1.

Data Sources and Method

Data Sources

A search was performed on Dissertation Abstracts using gender differences and visual-spatial skills as keywords. A total of 63 dissertation abstracts were listed. No limitations were made on the range of publication dates. Forty-three dissertations actually dealt with visual-spatial skills.

Method

The coding sheet includes sections on study characteristics, subject characteristics, instrument characteristics, and effect size calculation. A separate sheet was completed for each subgroup on each scale within a dissertation.

Measures

Sample Selectivity - The degree of selection by ability present within a research sample, i.e unselected (a local school, a national or statewide representation, etc.), somewhat selective (college or advanced courses), and highly selective (prestigious college, a gifted population).

Age - Average age of participants in study.

Year - The year that the study was conducted.

Linn and Petersen

Spatial Category -

Spatial Perception - Examples of tests are The Rod and Frame Test (Witkin, Dyk, & Faterson, 1962), and tasks that require a subject to draw or identify a horizontal line in a tilted bottle.

Mental Rotation - Examples include the Vandenberg and Kuse Mental Rotation Test (1978), Flags and Cards from the French Kit (French, et al., 1963), and Primary Mental Abilities (PMA) Space (Thurstone & Thurstone, 1941).

Spatial Visualization - Examples include The Embedded Figures Test, Hidden Figures, Paper Folding, Paper Form Board, etc.

Eliot and Smith

Category -

Spatial Recognition - Defined by the sub-categories of copying and maze tasks, embedded figures tasks, visual memory tasks, paper formboard tasks, and figural rotation tasks.

Spatial Manipulation - Defined by the sub-categories of block tasks, block rotation tasks, paper folding tasks, surface development tasks, and perspective tasks.

Multiple Task - Defined by combination tasks such as the Differential Aptitude Test Space Relations Test and the Group Embedded Figures Test.

Speed - Testing time/Number of items.

Effect size - $ES=g^*J=[(\overline{X}_M - \overline{X}_F)/S_p]^*[1-3/(4\{n_M + n_F - 2\})]$

When means and standard deviations were not available, effect sizes were estimated from ANOVA tables or t and F statistics:

$S_p=[(SS_{tot} - SS_{trt})/(N-2)]$

$F^{1/2}=t \quad g=t^*(1/n_M + 1/n_F)$

Standard Error of Effect Sizes -

$[(n_M + n_F)/(n_M n_F)] + ES^2/[2(n_M + n_F - 2)]$

Weighted Average Effect Size

$$\overline{ES} = [\Sigma ES_i/S_i^2]/[\Sigma 1/S_i^2]$$

Data Analysis

The goal of meta-analysis is to combine information from several studies. In some cases, several measurements were made on the same subgroup. To insure independence between data points, measurements within a specific visual spatial category for the same subgroup were averaged. A heterogeneity index was calculated to measure how much studies varied from the average effect size.

$$Q=\Sigma[(ES_i - \overline{ES})/S_i]^2$$

Q is based on the idea that the expected squared deviation of an effect size estimate from its true value equals the square of its standard error. A test of heterogeneity (variation in excess of sampling fluctuations) is carried out by comparing Q to a percentile of the Chi-square distribution with k-1 degrees of freedom.

A significantly large value for the heterogeneity index indicated that further analysis was needed to discern the sources of sampling variation. Plots were made of effect sizes for individual studies to locate both outliers and trends related to other study variables.

Results

A majority of these dissertations used college freshmen and sophomores as subjects. The earliest study was performed in 1974 and the latest in 1987. Ninety-one percent of the studies were performed from 1980 to 1987. The analysis of 150 independent data points from the 43 doctoral dissertations indicated a weighted average effect size across spatial ability categories of .205 (SE=.090). Males on the average were performing about .25 of a standard deviation better than females. Table 2 displays effect sizes after partitioning into the three spatial ability categories defined by Linn and Petersen. The spatial perception and mental rotations effect sizes were much smaller than the averages reported by Linn and Petersen. There seems to be no difference between males and females on spatial perception in marked contrast with Linn and Petersen's results weighted average effect size of .44. The weighted average effect size for mental rotation was smaller than the .73 reported by Linn and Petersen. The spatial visualization effect size average is essentially the same as that found by Linn and Petersen (ES=.13)

The results of the Eliot and Smith recategorization of effect sizes indicated that indeed the size of gender differences increased as complexity of task increased. The effect sizes, favoring males, were .13 (n=49) for recognition, .28 (n=55) for manipulation, and .24 (n=25) for multiple tasks. There was no significant difference between manipulation and multiple tasks. However, the effect size doubled between the recognition and manipulation categories.

As causes for heterogeneity within the categories defined by Eliot and Smith as spatial recognition and spatial manipulation, speed, year of study, and age of subjects were investigated. Only age of subjects within the spatial recognition and the spatial manipulation categories proved a source of heterogeneity. Within the recognition category, the effect size decreased with subjects 13 and over. However, the confidence intervals for these age divisions

overlapped to a large extent indicating no statistically significant differences. The analysis of variance and comparison of weighted average effect sizes within the spatial manipulation category shown in Tables 3 and 4 indicated that the effect sizes for ages 13 and over were significantly greater than those for ages under 13. This data would support hypotheses that sex differences in spatial ability could be related to changes occuring at puberty (either hormonal, environmental or genetic). The heterogenity index indicated that among subjects 18 and over in spatial recognition and ages 13 to 18 in spatial manipulation, there was a significant amount of variation. Closer examination of these studies indicated no trends among the measures collected within this meta-analysis.

Discussion

Using the visual spatial test classification developed by Eliot and Smith (1983), effect size favoring males increased with task complexity. The effect size doubled in magnitude from .13 for spatial recognition to .28 and .24 for spatial manipulation and multiple task tests. The magnitude of the effect sizes increased with the age of the subjects performing spatial manipulation tasks. There has been a suggestion made that the magnitude of effect sizes between the sexes may not have been entirely the result of differences in means (Benbow, 1988). A difference in variances between the sexes may have contributed significantly to the magnitude of effect sizes. This possibility was investigated by examining the ratio of male variance to female variance for the three complexity categories. Spatial recognition had a ratio of 1.14, spatial manipulation 1.32, and multiple task tests .96. As complexity increased from spatial recognition to spatial manipulation, scores for males were more variable than females.

Linn and Pertersen reported a speed factor with females performing less well than males on mental rotation tasks that included an element of speed. No speed factor was present in this data. Speed here was defined as the number of items per alloted time (provided within the test administration manual). A portion of the dissertations reported that they did not follow the standard administrative procedures.

Importance of Study

Whenever there is a difference between population groups on mental test data, it is important to discern the possible reasons for this difference. It has been reported in various journal articles that there is a definite gender difference in spatial abilities favoring boys. This analysis would seem to indicate that the gender difference reported in dissertations is not as large. When tasks are ranked as to cognitive task requirements, the effect sizes increased with complexity level. On closer examination, these effect sizes may have been more related to a higher variability among males than to a difference in means. The reasons behind increased variability among males should be the subject of further study.

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Table 1
Spatial Recognition
Special Aptitude: Spatial Relations Test
Subtest: Hidden Figures

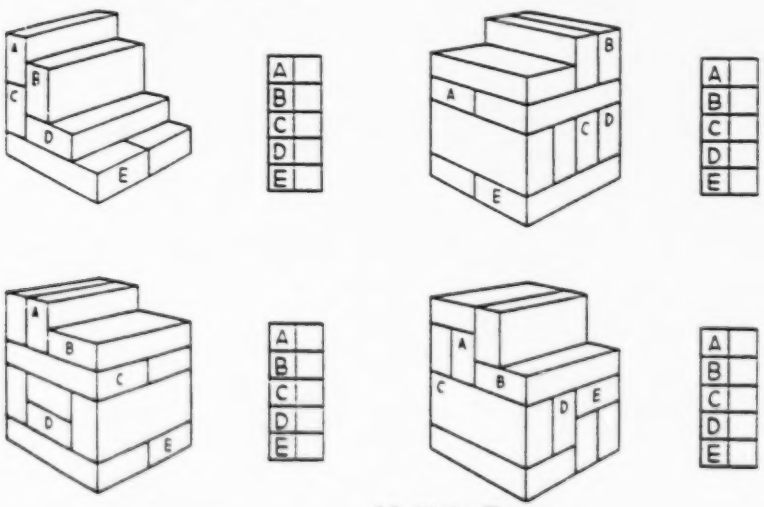
Test Instructions and practice items

In this section you are to determine which one of five simple figures, the patterns lettered A, B, C, D, and E at the top of each page, is contained in each of the more complex problem figures. There is **only one** lettered pattern in each problem figure. The pattern will always be right side up and will be the exact size and shape of one of the lettered patterns at the top of the page. Try sample problems I and II; then check your answers with the figures in the box below.

Spatial Manipulation
Thurstone's Primary Mental Abilities Tests
Subtest: Block Counting

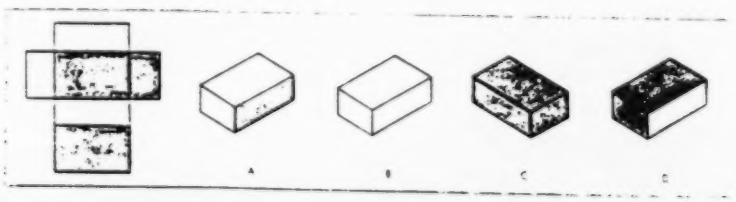
For each of the figures below, fill in the blank spaces to show how many blocks touch each of the lettered blocks. The blocks are all of the same size and shape.

Go right ahead. Do not wait for any signal.



Multiple Tasks
Differential Aptitude Test
Spatial Relations

EXAMPLE Y



In Example Y all the figures next to the pattern are correct in **shape**, but only one of them can be made from this pattern. Note that when the pattern is folded, the figure it makes will have three gray surfaces. Two of these will be the largest surfaces, either of which could be the top or the bottom of a box. The other will be one of the smallest surfaces, which would be one end of the box.

Table 2

Effect Sizes (ES) and Homogeneity for Spatial Ability Meta Analysis Using Linn & Petersen Categorization

Study Category	ES(N)	Weighted Estimation of ES	95%CI	Homogenity Statistic (Critical Value)
Spatial Perception:				
Linn & Petersen	62	.44	.04 - .84	110(80)
Druva-Roush & Wu	16	.03	-.21 - .27	77(25)
Mental Rotation:				
Linn & Petersen	29	.73	.50 - .96	247(43)
Druva-Roush & Wu	49	.43	.27 - .59	127(67)
Spatial Visualization				
Linn & Petersen	81	.13	-.24 - .50	98(101)
Druva-Roush & Wu	66	.17	-.03 - .37	177(84)

Table 3
Effect Sizes (ES) and Homogenity for Spatial Ability Meta Analysis
Using Eliot & Smith's Categorization

Category	ES(N)	Weighted Estimator of ES	95% CI	Homogeneity Statistic (Critical Value)
Recognition (all ages)	49	.13	-.01 - .27	170(67)
(under 13)	12	.32	.08 - .56	14(20)
(13 - 18)	17	.12	0 - .24	26(26)
(over 18)	20	.07	-.02 - .14	122(31)
Manipulation (all ages)	55	.27	-.13 - 1.07	212(71)
(under 13)	14	.17	-.07 - .41	13(22)
(13 - 18)	24	.51	.41 - .61	73(35)
(over 18)	17	.48	.34 - .62	37(28)
Multiple Tasks	25	.24	.14 - .34	38(36)

Table 4

ANOVA for Spatial Manipulation Category

Source	Degrees of freedom	Sum of Squares
Total	54	170.174
Age	2	47.317
Error	52	122.86

APPENDIX A

LIST OF DISSERTATIONS

Angelo, Sandra Ann (1981). The relationship between gender-role beliefs and spatial abilities in adolescents (Doctoral dissertation, Purdue University). Dissertation Abstracts International, 42, 11-B.

Anter-Ozer, Nur Serap (1982). Gender and handedness effects on tactile-spatial abilities (Doctoral dissertation, University of South Florida). Dissertation Abstracts International, 43, 05-B.

Baker, Justine Clara (1987). Spatial and verbal predictors of mathematics achievement among school students: Sex-related and maturational differences (Doctoral dissertation, University of pennsylvania). Dissertation Abstracts International, 48, 08-A.

Baldwin, Sharon L. (1984). Instruction in spatial skills and its effect on math achievement in the intermediate grades (Doctoral dissertation, University of Northern Colorado). Dissertation Abstracts International, 46, 03-A.

Batey, Andy H., JR. (1986). The effects of training specificity on sex differences in spatial ability (mental rotation, visualization, orientation, horizontality, field dependence-independence) (Doctoral dissertation, University of Maryland). Dissertation Abstracts International, 47, 06-B.

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Hoff, Anne Louise (1980). Sex and familial left-handedness as determinants of cerebral functional asymmetry for object recognition and spatial ability (Doctoral dissertation, Bowling Green State University). dissertation Abstracts International, 41, 10-B.

Hudson, Lisa (1986). Item-level analysis of sex differences in mathematics achievement test performance (self-confidence, learned helplessness) (Doctoral dissertation, Cornell University). Dissertation Abstracts International, 47, 02-B.

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Weiner, Neil Charles (1983). Cognitive aptitudes, personality variables, and gender differences effects on mathematical achievement for mathematically gifted students (Doctoral dissertation, Arizona State University). Dissertation Abstracts International, 44, 12-A.

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APPENDIX B

CLASSIFICATION OF VISUAL-SPATIAL TESTS

ID	TESTS	CAT	SPATCAT
1	1) Guay's Visualization of Views	10	3
	2) Vandenberg's Test of Three-dimensional Spatial Visualization	7	2
2	1) Thurstone's Primary Mental abilities Test	7	3
5	1) Group Embedded Figures Test	11	3
	2) Career Planning program: Form H (ACT Career Planning, space relations)	6	3
	3) Interrelations among set of blocks in 3 dimensions	.	.
6	1) Shepard and Metzler Tasks	7	2
7	1) Identical Blocks Test	7	2
	2) Group Embedded Figures Test	11	3
8	1) Flexibility of Closure	2	3
9	1) Differential Aptitude Test (Space relations)	11	3
	2) Vandenbery and Kuee's version of Shepard and Metzler's task	7	2
	3) Group Embedded Figures Test (GEFT)	11	3
	4) Piaget's Horizontal	.	1
10	1) Card Rotations (2-D)	5	2
	2) Mental Rotation (S & M)	7	2
	3) Paper Form Board	4	3
	4) Paper folding (ETS)	8	3
	5) Hidden Figures (ETS)	2	3
13	1) Concrete Pictures	2	3
	2) Recall or Recognition of Forms	.	.
14	1) Paper Folding Test (French)	8	3
	2) Cube Comparison (French)	9	2
15	1) Stafford Identical Blocks Test	7	3
16	1) ETS Card Rotation	5	2
	2) ETS Form Board	4	3
	3) ETS Surface Development	9	3
	4) Mental Rotation (Vandenberg's 3-D Spatial Vis)	7	2
	5) Elithorn's Perceptual Maze Test	6	1
17	1) Stafford Identical Blocks	7	3
	2) Orientation	1	.
	3) Block Design of WAIS	4	3

	4) Embedded Figures Test	11	3
18	1) DAT - Space Rotation (Differential Aptitude Test)	11	3
	2) Hidden Patterns	2	3
	3) Washington College Spatial Subtest	11	3
	4) Mental Rotation Test	7	2
19	1) Embedded Figure Test - ETS	2	3
	2) Card Rotations	5	2
	3) Paper Folding (Guilford)	8	3
	4) Surface Development (Kit Reference)	9	3
	5) Horizontal/vertical Rotations (adapted from S-M)	7	2
	6) Stumpf Cube Test	10	2
20	1) Purdue Spatial Visualization	11	3
	2) DAT - Spatial Rotation	11	2
21	1) ETS Card Rotation	5	2
	2) Thurstons Hands	5	2
	3) GATB General Aptitude	.	.
	4) Revised Minnesota Paper Form Board Test	4	3
	5) Group Embedded Figures Test (GEFT)	11	3
22	1) DAT Space Rotations Test	11	2
23	2) Hidden Pattern Test	2	3
24	1) Rotation of Alphanumeric Character	2	2
	2) DAT Space Rotation	11	2
25	1) Group Embedded Figure Test (GEFT)	11	2
	2) Rod and Frame	.	.
	3) Block Design of WAIS	6	3
	4) DAT Space Rotation	11	2
	5) Thurstone's Mechanical Apt tests (MAT 2-D)	4	3
	6) MAT (3-D)	11	3
	7) Minnisota Form Board (MFB)	4	3
	8) Blocks of AGCT	6	3
26	1) Group Embedded Figure Test and DAT	11	3
27	1) Primary Mental Abilities:Spatial	5	2
	2) WISC Block Design	6	3
	3) WISC Mazes	1	1
	4) Mental Rotation(Shepard and Metzler adopted)	7	2
	5) WPPSI Block Design	6	3
	6) WPPSI Mazes	1	1
28	1) Vanbenbery mental Rotation Tasks	7	2
	2) Minnesota Form Board	4	3
29	1) PMA Space	5	.

	2) Children's Embedded Figures	2	3
30	1) Hidden Patterns	2	3
	2) Hidden Figure (Kit Reference)	7	3
	3) Card Rotation	7	2
	4) Cube Comparison	7	2
	5) Form Board	4	3
	6) Paper Folding (Kit reference)	8	3
	7) Surface Development (Kit Reference)	9	3
31	1) Group Embedded Figure Test	11	3
	2) DAT Space	11	3
32	1) Space Exploration Test	10	3
	2) Thurstone's Flages	5	2
	3) Thurstone's Paper Folding	8	3
33	1) Monash Space Visualization Task	.	.
34	1) WISC Block Design	6	3
35	1) Hand Rotation Task	5	2
	2) Street Closure Test	3	.
	3) CAB Embedded Figure Test (Comprehensive Ability Battery)	2	3
	4) CAB Mental Rotation	5	2
	5) Purdue Pegboard	1	.
36	1) Thoustone's Flages	5	2
37	1) Number Comparison Test	.	.
	2) Hidden pattern test	2	3
	3) Card Rotation Test	7	2
38	1) Group Embedded Figure Test (Witkin)	11	3
39	1) Rotated Figures (Lithus)	5	2
40	1) Thurstone's flags Test	5	2
	2) Purdue Spatial Visualization Test	7	3
41	1) ETS Card Rotations	7	2
	2) Mental Rotations (Shepard & metzler)	7	2
	3) Thurstone's Block Counting	6	3
	4) Guilford & Zimmerman Spatial Visualization	7	3
	5) ETS Form Board	4	3
	6) ETS Surface Development	9	3
42	1) DAT Space Relations Test	11	3
43	1) Space (Primary Mental Abilities)	5	2
	2) Close Ups (Guilford)	.	.
	3) Circle Continuation (Guilford)	.	.
	4) Match problems (Merrifield & Guilford)	4	3

5) Gottschaldt Hidden Figures test	2	3
6) Making Objects	.	.

Note: ID : Identification Number of Dissertation
CAT: Eliot & Smith's Category
SPATCAT: Linn & Petersen's Category

APPENDIX C

LIST OF TEST BY DISSERTATION

TESTS	ID
1. Block Design of WAIS	17, 25,
2. Block of AGCT	25,
3. CAB Embedded Figure Test (Comprehensive Ability Battery)	35,
4. CAB Mental Rotation	35,
5. Card Rotation	10, 19, 30, 37,
6. Career Planning Program (Form H) (ACT Career Planning, Space Relations)	2,
7. Children's Embedded Figures	29,
8. Circle Continuation (Guilford)	43
9. Close Ups (Guilford)	43,
10. Concrete Pictures	13,
11. Cube Comparison (French)	14,
12. Cube Comparison (Kit Reference Tests)	30,
13. DAT Space Relations Test (Differential Aptitude Test)	9, 18, 20, 22, 24, 25, 31, 42,
14. Elithorn's perceptual Maze Test	16,
15. Embedded Figure Test	17,
16. Embedded Figure Test (ETS)	19,
17. ETS Card Rotations	16, 21, 41,
18. ETS Form Board	16, 41,
19. ETS Surface Development	16, 41,
20. Flexibility of Closure	8,
21. Form board	30,
22. GATB General Aptitude	21,

23. Group Embedded Figure Test (GEFT)	5, 7, 9, 21, 25, 26, 31,
24. Group Embedded Figure Test (Witkin)	38,
25. Gottschaldt Hidden Figures Test	43,
26. Guay's Visualization of Views	1,
27. Guilford & Zimmerman Spatial Visualization	41,
28. Hand Rotation Test	35,
29. Hidden Figures (ETS)	10,
30. Hidden Figures (Kit Reference Tests)	30,
31. Hidden Patterns	18, 23, 30, 37,
32. Horizontal/Vertical Rotation (adopted from S-M)	19,
33. Identical Blocks Test	7,
34 Interrelations among set of Blocks in 3-D	5,
35. Making Objects	43,
36. Match Problems (Merrifield & Guilford)	43,
37. Mental Rotation (Shepard & Metzler)	41,
38. Mental Rotation (S & M adopted)	27,
39. Mental Rotation (S & M tasks on computer)	18,
40. Minnesota Form Board	25, 28,
41. Monash Space Visualization Test	33,
42. Number Comparison Test	37,
43. Orientation	17,
44. Paper Form Board	10,
45. Paper Folding (ETS)	10,
46. Paperfolding (Kit Reference Tests)	30,
47. Paper Folding (Guilford)	19
48. Paper Folding (French)	14,

49. Piaget's Horizontal 9,

50. Primary Mental Abilities: Spatial 27,

51. PMA Space 29,

52. Purdue Spatial Visualization 20, 40,

53. Purdue Pegboard 35,

54. Recall and Recognition of Forms 13,

55. Revised Minnesota Paper Form Board 21,

56. Rotated Figures (Lithus) 39,

57. Stafford Identical Blocks 15, 17,

58. Shepard & Metzler Tasks 6,

59. Stumpf Cube Test 19,

60. Rotation of Alphanumeric Character 24,

61. Rod and Frame 25,

62. Space (Primary Mental Abilities) 43,

63. Space Exploration test 32,

64. Street Closure Test 35,

65. Surface Development (Kit Reference tests) 19,

66. Thurstone's Hands 21,

67. Thurstone's Mechanical Aptitude (MAT 2-D) 25,

68. Thurstne's MAT 3-D 25,

69. Thurstone's Flages 32, 36, 40,

70. Thurstone's Paper Folding 32,

71. Thurstone's Block Counting 41,

72. Thurstone's primary Mental Abilities Test 2,

73. Vandenberg's Test Of 3-D Spatial Visualization 1, 16,

74. Vandenbery and Kuee's version of Shepard & Metzler's test 9,

75. Vandenbery Mental Rotation Tasks 28,

76. Washington College Spatial Subtest 18,

77. *WISC Block Design* *27, 34,*

78. WISC Mazes 27,

79. WPPSI Block Design 27,

80. WPPSI Mazes 27,